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K. Ya. Kondrat'yev, A. A. Buznikov, O. B. Vasil'yev,
B. V. Vinogradov, A. A. Grigor'yev, Yu. I. Rabinovich,
L. I. Chapurskiy

Translation of "Nekotoryye rezul'taty sovmeshchennogo kompleksnogo podsputnikovogo geofizicheskogo eksperimenta," Akademii Nauk SSSR Doklady, Vol. 196 (6), 1971, pp 1333-1336

FACILITY FORM 602
N72-14378 (ACCESSION NUMBER)
8 (PAGES)
(NASA CR OR TMX OR AD NUMBER)
(THRU) 63 (CODE)
13 (CATEGORY)
JAN 1972 RECEIVED NASA STI FACILITY INPUT BRANCH

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546
NOVEMBER 1971

SOME RESULTS OF THE INTEGRATED COMPOSITE SUBSATELLITE GEOPHYSICAL EXPERIMENT

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ABSTRACT. A brief overview of some of the results obtained from the integrated mission carried out by Soyuz 6 and Soyuz 7 and LI-2 and IL-18 aircraft to photograph and make spectrophotometric measurements of the earth's surface along the track Caspian Sea-Ust'-Urt-Aral Sea is provided. The article fails to describe, or analyze, the photography.

The field in which manned spacecraft can be used to study the earth's surface (including investigations of its natural resources) based on information obtained from optical, radar, and other types of observations, is constantly expanding. /1333*

Today, optical research methods yield the largest volume of information from space on the subjacent surface. The program of scientific experiments planned for the spacecraft Soyuz 6 and Soyuz 7 included photography and spectrophotometry of the earth's surface along the track Caspian Sea-Ust'-Urt-Aral Sea, in order to solve the problems indicated. LI-2 and IL-18 aircraft, equipped with complex instrumentation, including instruments similar to those installed in the spacecraft, flew this track to obtain information on the atmosphere's transfer function. Ground groups simultaneously provided a physical-geographical description of the surface along the flight path. Plans called for an integrated experiment at a selected point on the track with a ground group, the aircraft, and the spacecraft participating simultaneously. The integrated experiment took place on 12 and 13 October 1969. Spectrophotometry of the subjacent surface in this region was taken by Soyuz 7 on 13 October 1969 only.

This report contains a brief overview of some of the results, but descriptions and analysis of the photography from the aircraft and the spacecraft are not included.

Spectrographic measurements were made of the subjacent surface by Soyuz 7

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* Numbers in the margin indicate pagination in the foreign text.

at the nadir through the porthole using an RSS-2 manual spectrograph and the procedure described in the reference [1]. Reference [2] contains a description of the schematics and operating principle of the RSS-2. The spectral range of the instrument covers the portion between 430 - 690 m μ ("type 15" photographic film was used in the spectrograph). The linear dispersion in the instrument was 166 Å/mm, and this provides a spectral resolution ~50 Å for a slit width of 0.3 mm. The observations made from the IL-18 aircraft, in addition to the aerial photographic survey, included measurements of the ascending fluxes of shortwave and long-wave radiation (λ=0.3 - 3μ and λ=3 - 30μ), infrared radiation (λ=2.8 - 5.6μ), microwave radiation (λ=3.2 cm), and spectral measurements in the bands of long waves 0.4 - 0.85, 0.9 - 2.6, and 2.2 - 5.4 μ from an altitude of 8,000 m. The LI-2 aircraft carried an RSS-2 spectrograph and a set of photoelectric spectrometers operating in the spectral band from 300 to 900 m μ [4]. The LI-2 aircraft flew the spacecraft track at an altitude of 800 m on 12 October and at 2,700 m on 13 October. The portions of the spectra of the subjacent layer obtained with the RSS-2 on 13 October 1969, from Soyuz 7 at an altitude of 219 km, and from the aircraft at an altitude of 2,700 m, were published in the preceding report [3].

Thin cirrus clouds were observed at an altitude of 9,000 m over the eastern and western parts of the territory discussed on 12 October 1969, but these had very little effect on the optical properties of the atmosphere. The cumulus /1334 cloud cover over the eastern part of the Ust'-Urt Plateau was between two and five tenths, with the altitude of the lower level at 1,000 m. The Aral Sea area was cloudless. Very little haze was in the air. Visibility was about 10 km in the western part and was up to 20 km in the eastern part. The Caspian Sea reported light seas (force 1) and a surface temperature of 14 - 15° C. Surface temperature of the clay flats on the flat, loamy-gravelly surface of the Ust'-Urt Plateau was about 19° C, that of the gravelly surface about 22° C. The Aral Sea reported light seas and swell, force 1 - 2, and a surface temperature of 16° C.

Aerial photography along the spacecraft flight path was taken within the limits of the photoactinic flux for λ=590 - 680 m μ. This provided a detailed

picture of the distribution of the optically homogeneous surfaces and served as the base for closing all the other recorded data.

Fluxes of reflected radiation were measured by wide-angle receivers with a 130° angle of view in the λ=0.3 - 3 μ band. Surface albedo (A) was calculated from these latter. A depends on the type of subjacent surface and on the state of the atmosphere. The least magnitudes, A=10 - 15%, were observed over the sea surface. The surfaces of the salt deposits of the northern Kara-Bogaz-Gol, and of Barsa-Kel'mes, have high albedo values 32 - 41%. Moderate albedo values, 20 - 30%, are characteristic of the clayey and clayey-gravelly surfaces of the Ust'-Urt Plateau.

The ascending fluxes of long-wave radiation (E) were measured by wide-angle receivers in the λ=3 - 30μ band. The hottest are the loamy and loamy-gravelly surfaces of the plateau (E= 0.50 - 0.53 cal/cm^2-min). The alkali flats are not as hot at these times (E= 0.45 - 0.48 cal/cm^2-min). Minima, E = 0.44 cal/cm^2-min, were recorded over the Caspian Sea. Small differences in the total long-wave radiation over inhomogeneous surfaces can be explained by the great compensating effect of the optical thickness of the atmosphere in this interval of the spectrum.

A spectrometer with a 1° angle of view was used to obtain spectral brightness (B_λ) in the band λ = 0.4 - 2.6 μ. These data can be used to differentiate individual types of surfaces by intensity and by the location of the B_λ maxima in the visible and near infrared regions of the spectrum (λ = 0.40 - 0.83μ). Brightest are the salt surfaces, with B_λ approximately (2 - 3)$\cdot 10^{-3}$ w/cm$^2\cdot$sterad$\cdot\mu$, with a monotonous, almost horizontal movement of B_λ through the spectrum, corresponding to the visual white light of the surface. Somewhat darker are the sandy salt crusts with B_λ about (1.4 - 2.6)$\cdot 10^{-3}$ w/cm$^2\cdot$sterad$\cdot\mu$, corresponding to a visually light-gray light. Least values, $B_\lambda \approx$ (2 - 5)$\cdot 10^{-4}$ w/cm$^2\cdot$sterad$\cdot\mu$, with pronounced max B_λ of about 0.5μ, are found for the water expanses with visually dark-blue, blue-green colors. Differentiable within the limits of the plateau are: (1) surfaces with a broad clay flat development and high B_λ = (1.2 - 3)$\cdot 10^{-3}$ w/cm$^2\cdot$sterad$\cdot\mu$, accompanied by a shift in max B_λ in the red region of the spectrum; (2) surfaces with relatively denser vegetation, visually darker (B_λ = (0.9 - 2.6)$\cdot 10^{-3}$ w/cm$^2\cdot$sterad$\cdot\mu$ with $\max_1$ when λ=0.55μ and $\max_2$ when λ=0.75μ and a minimum when λ=0.65 - 0.7μ; (3) surfaces with intermediate structures

($B_\lambda = (0.7 - 2) \cdot 10^{-3} w/cm^2 \cdot sterad \cdot \mu$).

Less perceptible are the differences in B_λ for these same surfaces recorded in the λ=0.9 - 20μ band, the result of the great optical thickness of the atmosphere in this band. It was noted, however, that the reflective and radiative characteristics increase somewhat with increase in wavelength in the band from 0.9 to 2.6 μ.

A scanning radiometer with an angle of view of 12', operating in the band λ= 2.8 - 5.6μ, was used to measure the infrared radiation (T_{rad}) in the atmosphere's transmission window. Heat images of the terrain, and radiation temperature values, were obtained in this region of the spectrum. The water surfaces /1335 are coldest, T_{rad} = 3.6 - 6.8° C. The clayey-gravelly and gravelly surfaces provided the highs, T_{rad} = 11.9° C. T_{rad} was particularly high on the Karabaur ridges (up to 15.1° C). The alkali flats stand out because of their low values, T_{rad} = 9.6° C. Sporadic cloudiness resulted in a 5° to 6° C reduction in T_{rad}. The day time heat picture was subject to the distorting influence of the reflected radiation, and to that of absorption by the atmosphere, despite the fact that the difference in thermal characteristics in this band was found to be quite detailed.

A microwave radiometer with an angle of view of 6° and a real resolution of 800 x 800 meters when used at an altitude of 8,000 meters, was used to measure the spectrum when λ = 3.2 cm. Radio brightness temperatures (T_b,°K) were analyzed. A comparison between the distribution of T_b values and conditions in the atmosphere and the condition of the ground surface revealed the following.

Highest T_b in the day time is characteristic of the loamy-gravelly surfaces of the limestones on the Ust'-Urt Plateau (T_b=249 - 267°K). Minimum T_b values occurred on the sea surfaces, but the T_b values over the seas changed little, something that reflects the small textural and thermal gradients at the sea surface. Increased values, T_b= 156 - 157° K, were observed over the dry salt crusts of the Kara-Bogaz-Gol. The gypsums and the rim of the sanded alkali flats yielded intermediate values, T_b= 219° K. T_b increased to 249 - 261°K over the rocky desert of the Ust'-Urt Plateau and the sand spit of the Kara-Bogaz-Gol

(changes in exposure and surface roughness account for the significant variations in T_b). T_b measurements thus were helpful in making a sharp differentiation between several types of landscapes; sandy, rocky and clayey, alkali flat, gypsum-sand, and water surface. Landscapes with different ratios of stone and clay deserts can be differentiated within the limits of the Ust'-Urt Plateau. Areas with a predominance of flat clay surfaces almost devoid of vegetation yielded low T_b at that time. The areas with a predominance of darker gravel surfaces had higher T_b values.

There is, therefore, a positive, as well as a negative, correlation between the readings of the individual receivers of reflection and radiation. The sea surface yields the lowest A, E, T_{rad}, T_b, $B_{\lambda 14-16\mu}$ and $B_{\lambda 0.4-0.5\mu}$ values. The sand spit has moderate A values that differ little from those for the alkali flats, but they are sharply distinguishable in terms of the submaximal magnitudes of T_{rad} and T_b. The western part of the Kara-Bogaz-Gol, flooded by heated water, differs from the fried out salt crusts of the eastern part by lower A and B_λ, but has on the other hand, higher T_{rad}. The alkali flats are featured by high A and B_λ, low T_{rad}, and uniform B_λ over the entire spectrum. The surface of the stone plateau has moderately high A, B_λ, T_{rad}, T_b, values as compared with other surface elements, as well as a brightness value that increased in the red region of the spectrum when $\lambda=0.6 - 0.7\mu$. An increase in the area of the clay flats on the stone plateau results in an increase in A, T_{rad}, and max B_λ, and in a decrease in T_b. Slopes with a southern exposure are distinguishable by the increase in T_{rad}, although the T_b value remains at about the same level. Sporadic cloudiness (cloud cover 2/10 to 5/10) increases A and decreases T_{rad}, but is reflected only slightly in the T_b values. Denser vegetation is distinguishable by a decrease in B_λ and by the presence of a max B_λ when $\lambda=0.5 - 0.6\mu$, and $\lambda \geq 0.8\mu$.

We note, in conclusion, that each remote indication method provides specific, but limited, and often not reliable enough, information on the status of the subjacent surface, ocean, or atmosphere. Only the integrated use of a complex of methods for recording the earth's electromagnetic field in different regions of the spectrum, each refining and complementing the other, will enable us to obtain sufficiently reliable, standardized, and detailed information on the natural /133 environment by remote methods. Needles to say, this article simply is an illustration of available capabilities. The practical solution for the problem can be arrived at only by the development of a procedure for the

statistical analysis of composite radiation data.

Leningrad State University im. A. A. Zhdanov
Main Geophysical Observatory im. A. I. Voyeykov
Leningrad

Submitted
25 August 1970

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Translated for Goddard Space Flight Center under contract NASw-2038 by Translation Consultants, Ltd., 944 So. Wakefield St., Arlington, Virginia 22204.